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OF
CIVIL ENGINEERS



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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

NOTICE OF REGULAR MEETING.

A REGULAR meeting of the Boston Society of Civil Engineers will be held on

WEDNESDAY, OCTOBER 17, 1917,

at 7.45 o'clock P.M., in CHIPMAN HALL, TREMONT TEMPLE, BOSTON.

Mr. Henry I. Harriman, president of the New England Power Company, will read a paper entitled, "Water Powers of New England." The paper will deal not only with the water powers of the New England Power Company, but with other hydro-electric developments and economic questions that underlie their construction and utilization.

The paper will be illustrated with lantern slides.

S. E. TINKHAM, *Secretary*.

PAPERS IN THIS NUMBER.

"Aviation as Applied to the Navy." George D. Murray.

"Continuous Beams of Unequal Spans." Frank S. Bailey.

"Classification of Civil Engineers under the Civil Service."

Report of the Committee.

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

REPORT OF THE MILITARY COMMITTEE ON EQUIPMENT FUND FOR THE 101ST UNITED STATES ENGINEERS.

BOSTON, MASS., October 2, 1917.

TO THE BOSTON SOCIETY OF CIVIL ENGINEERS:

At a regular meeting of the Society held May 16, 1917, the Board of Government recommended the adoption of the following resolution:

Whereas, engineers and engineer troops are of prime importance in modern warfare, and

Whereas, the organization of engineer troops is particularly a subject for coöperation on the part of societies of engineers, and

Whereas, a regiment of engineers is now being organized in the Massachusetts National Guard, by the transformation and enlargement of the First Corps of Cadets; therefore

Be it resolved, that the Boston Society of Civil Engineers endorses the formation of such regiment of engineers, and *pledges to it its support and assistance.*

This resolution was unanimously adopted by the meeting, and, in accordance with the provisions of the constitution, was submitted to the full membership by letter ballot.

At the regular meeting held on June 13, 1917, the letter ballot was canvassed, with the result that 296 members voted in the affirmative and 8 in the negative.

In order properly to carry out the purport of this resolution, it was suggested that our committee take some substantial action which would make manifest the sincerity of purpose embodied in the resolution. Accordingly the committee decided to solicit voluntary subscriptions from the members of the Society, looking to the creation of a fund which should be available for the purpose of necessary or desirable equipment not customarily supplied by the War Department and which might add to the efficiency or comfort of the men in this organization.

A circular was mailed to the membership of the Society on June 29, 1917, followed by a second appeal on July 18, 1917, outlining the necessity for such action and requesting subscriptions for the creation of such a fund, the disposition of the fund to be determined by the Board of Government of the Society. As a result of these appeals, a total of \$2 220 has been received by the Secretary, divided as follows:

5 subscriptions of	\$100.00 each.
4 subscriptions of	50.00 each.
11 subscriptions of	25.00 each.
9 subscriptions of	20.00 each.
4 subscriptions of	15.00 each.
64 subscriptions of	10.00 each.
1 subscription of	7.50
58 subscriptions of	5.00 each.
2 subscriptions of	4.00 each.
3 subscriptions of	3.00 each.
1 subscription of	2.50
15 subscriptions of	2.00 each.
18 subscriptions of	1.00 each.

195 Total amount, \$2 220.00

Early in the month of August a conference was had with Colonel Bunnell of the Engineer Regiment, in order to learn if possible what articles of special equipment appealed to him as being most desirable for the needs of the regiment. He very frankly stated that there was a great variety of articles which were not included in the regular equipment of an engineer regiment, the possession of which would add very materially to the efficiency of his organization, but in the absence of a definite knowledge of the particular class of service to which his regiment would be assigned, he could not then make an intelligent selection. He suggested, however, in view of this uncertainty, that perhaps the fund could be better applied to its purpose if it were turned over intact to the regiment, to be expended as and when future circumstances might dictate. Colonel Bunnell's suggestion was submitted to the Board of Government on August 24, and after discussion the Board voted to instruct the Secretary to transfer the money in the fund to Colonel Bunnell, to be expended as his judgment might dictate.

The following correspondence taken from the files of the Society is self-explanatory:

BOSTON SOCIETY OF CIVIL ENGINEERS.

BOSTON, August 27, 1917.

Col. GEO. W. BUNNELL,

101ST REGIMENT, U. S. ENGINEERS,

CADET ARMORY, COLUMBUS AVE., BOSTON, MASS.

Dear Sir, — At a meeting of the Board of Government of the Boston Society of Civil Engineers, held on August 24, 1917, the following vote was passed:

"Voted, that the equipment fund for the Massachusetts Engineer Regiment now on hand, or which may be contributed later, be turned over to Colonel Bunnell of the 101st Regiment, United States Engineers, to purchase such emergency equipment for the benefit of the regiment as his judgment may dictate."

There is now on deposit in the Old Colony Trust Co., to the credit of this fund, the sum of \$2 200, and I have the pleasure of enclosing a check for this sum payable to your order.

BOSTON SOCIETY OF CIVIL ENGINEERS.

As you already know, this fund was contributed by members of the Society for the purpose of furnishing the regiment with certain equipment not ordinarily supplied by the War Department, which would add to the efficiency of your organization.

After a conference with you, the chairman of our Committee on Military Affairs, Mr. Charles R. Gow, reported to the Board of Government of the Society that under present conditions it seemed advisable to turn the fund over to the regiment for such expenditure as you should deem to be for its best interests, rather than to purchase special equipment which later might not be found to be useful.

Extending to the officers and men of the Engineer Regiment the best wishes of the Boston Society of Civil Engineers, I am

Very truly yours,

(Signed) S. E. TINKHAM, *Secretary.*

FIRST CORPS CADETS, 1ST REGIMENT MASS. ENGINEERS, N. G.

COLUMBUS AVENUE, BOSTON, August 29, 1917.

S. E. TINKHAM, Esq., *Secretary,*

BOSTON SOCIETY OF CIVIL ENGINEERS,

BOSTON, MASS.

My dear Mr. Tinkham, — I take pleasure in acknowledging your favor of the 27th instant, inclosing check to my order from the Military Equipment Fund of the Society for twenty-two hundred dollars.

On behalf of the regiment I wish to express its sincere thanks for this gift, and particularly for the spirit that prompted it. It is certain that the money itself, which is to be used to purchase such emergency equipment for the benefit of the regiment as my judgment may dictate, gives the regiment a certain advantage over other engineer regiments, and will better enable it to perform its duty in the service of our country in such a way, or to such extent, as will make all of us proud of its record.

The officers and men of the regiment thank the Boston Society of Civil Engineers for its good wishes, and for the token of these good wishes which has been expressed in this substantial way.

Very sincerely yours,

(Signed) GEO. W. BUNNELL,

Colonel, 101st U. S. Engineers.

Since the date of Secretary Tinkham's letter, there has been contributed the additional sum of \$20 which, in accordance with the provisions of the vote of the Board of Government, will also be turned over to Colonel Bunnell.

For the Committee on Military Affairs,

CHARLES R. GOW, *Chairman.*

MINUTES OF MEETING.

BOSTON, September 19, 1917. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order by Vice-President Lewis M. Hastings, at 8 o'clock. There were 140 members and visitors present.

The record of the June meeting was read and approved.

The Secretary reported for the Board of Government that it had elected to membership in the grade of member Mr. Gardner Sabin Gould, and in the grade of junior Mr. Edward Andrus Terhune, Jr., and that it had also elected to honorary membership John R. Freeman, George F. Swain, Ira N. Hollis and Howard A. Carson.

The Secretary read a communication from Mr. E. F. Rockwood, a member of the Society, and chief engineer of the New England Concrete Construction Company, requesting this Society to join with the Boston Society of Architects and the Master Builders Association in the appointment of a joint committee to prepare and submit to the next legislature a revision of the structural portion of the Boston Building Laws. On motion of Mr. Bryant, the communication was referred to the Board of Government with full powers.

The Secretary announced the death of Stanley A. Miller, a member of the Society, which occurred on May 13, 1917. By vote the Chair was requested to appoint a committee to prepare a memoir, and Mr. William H. Balch has been appointed.

Mr. Gow, for the Committee on Military Affairs, submitted a report which is printed in the October, 1917, number of the JOURNAL of the Society.

Mr. Frank A. Barbour was then introduced and gave a most interesting account of the cantonment construction work at Camp Devens, Ayer, Mass., of which he was the supervising engineer. The talk was very fully illustrated with lantern slides.

Other speakers were Captain Edward Canfield, Jr., U.S.A., construction quartermaster; Major Glen I. Jones, sanitary officer; Mr. Frank Rogers, general manager for the Fred T. Ley

Co., the contractors for the work; and Mr. Leonard Metcalf, a member of the Society.

After passing a vote of thanks to the several speakers of the evening, for their courtesy in presenting in so interesting a manner the building of the cantonment at Ayer, the meeting adjourned at 10.30 o'clock.

S. E. TINKHAM, *Secretary*.

APPLICATIONS FOR MEMBERSHIP.

[October 4, 1917.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission, and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

ALLEN, ELMER FOREST. Medford, Mass. (Age 24, b. Cliftondale, Mass.) Student for two years with International Correspondence Schools, course in surveying and mapping; is now third-year student at Northeastern College (Y. M. C. A.) Engrg. School, structural engineering course. From March, 1917, to date, draftsman with bridge department, B. & M. R. R. Refers to A. S. Coombs, C. S. Ell, J. B. Mailey and L. J. Phillips.

LOHMEYER, WILLIAM, Jr. Cambridge, Mass. (Age 22, b. Charleston, W. Va.) Graduate of Virginia Military Inst., 1912, degree of B.S.; is now senior at Mass. Inst. of Technology. Refers to J. B. Babcock, G. L. Hosmer, J. W. Howard, Dwight Porter, A. G. Robbins and C. M. Spofford.

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WELLS, EDWARD PIERCE. Malden, Mass. (Age 20, b. Boston, Mass.) Student for one year at Lowell Inst. School for Industrial Foremen. Was for one year (1915) in employ of McGunigle & Taunge on underground electrical construction; has been for two years (1916 and 1917) draftsman with Aberthaw Construction Co. Refers to L. H. Allen, R. E. Parker, A. B. Mac-Millan and F. S. Wells.

LIST OF MEMBERS.

HONORARY MEMBERS.

(Elected September 19, 1917.)

CARSON, HOWARD ADAMS.

FREEMAN, JOHN RIPLEY.

HOLLIS, IRA NELSON.

SWAIN, GEORGE FILLMORE.

CHANGES IN ADDRESS.

ATWOOD, THOMAS C.....485 Edgewood Ave., New Haven, Conn.

BALCH, WILLIAM H.....Capt., E. O. R. C., Am. Univ., Washington, D. C.

BARNES, ARTHUR B.....650 Hanover St., Fall River, Mass.

BURLEIGH, WILLARD G.....Corp., 25th Engrs., Ayer, Mass.

CASEY, JOHN J.....81 Moreland St., Roxbury, Mass.

COREY, KENNETH T.....19 Lenox St., Springfield, Mass.

COWAN, HENRY E.....East Milton, Mass.

FOSTER, HOWARD L.....17 Paul St., Watertown, Mass.

GERRISH, HERBERT T., Lieut., Camp American University, Washington, D. C.

HANF, FRANK S.....2d Lieut., 305th Engrs., Camp Lee, Petersburg, Va.

HUBBARD, CARL P.....Sergt., Co. D, 11th Engr. Regiment,

Care of American Expeditionary Force, Paris, France.

JERRETT, ROBERT.....115 Beckwith St., Elmwood Sta., Providence, R. I.

KATZ, HARRY L.,

Care of Supervising Engr.'s Office, Camp Meade, Baltimore P. O., Md.

LEONARD, JOSEPH F. A.....2d Lieut., E. O. R. C., 102d Engrs., U. S. A.,

Camp Wadsworth, Spartanburg, S. C.

MAYNARD, FORREST J.....22 Broadway, Watertown, Mass.

MCNULTY, RICHARD J.....Care of Charles F. Berrill, No. Lexington, Mass.

MEADE, ROYAL L.....10 and 12 Pearson St., Chicago, Ill.

NASH, PHILIP C.,

Lieut., E. O. R. C., U. S. A., Am. Univ. Training Camp, Washington, D. C.

RAND, ROBERT.....Lieut., j. g., U. S. Naval Reserve Force,

Communication Office, Bldg. No. 24, Navy Yard, Boston, Mass.

SAVILLE, THORNDIKE.....53 No. Beacon St., Hartford, Conn.

SEARS, CALVIN C.....3 Bryan Ave., Branford, Conn.

SKILLIN, FRED B.,

Care of J. W. Zisgen, Interstate Commerce Comm., Washington, D. C.
VESPER, ROBERT A. 243 Harvard Ave., Allston, Mass.

WADE, W. NEWELL 42 Park Vale Ave., Suite 2, Allston, Mass.

WARING, CHARLES T.,

Major, Signal Corps, Chamber of Commerce Bldg., Fort Worth, Tex.
WESTON, ARTHUR D. Lieut., 26th Engr. Regiment, Camp Dix, N. J.

WHITNEY, RALPH E. Lieut., 98 Mountfort St., Suite 6, Boston, Mass.

YOUNG, ERVING M. Meade Branch, Baltimore P. O., Md.

DEATH.

PIERCE, FRANK A. August 7, 1917

LIBRARY NOTES.

RECENT ADDITIONS TO THE LIBRARY.

On Military Engineering and Related Subjects.

Naval Architecture. Cecil H. Peabody.

Practical Shipbuilding, 2 vols. A. Campbell Holms.

U. S. Government Reports.

Analyses of Coals Purchased by the Government during
Fiscal Years 1908-1915. George S. Pope.

Asbestos in 1916. J. S. Diller.

Asphyxiation from Blast-Furnace Gas. Frederick H. Willcox.

Chemical Relations of Oil-Field Waters in San Joaquin
Valley, California. G. Sherburne Rogers.

Contributions to Economic Geology, 1916: Part I. —
Metals and Non-metals except Fuels. F. L. Ransome and Hoyt
S. Gale. Part II. — Mineral Fuels. David White and others.

De Soto-Red River Oil and Gas Field, Louisiana. George
Charlton Matson and Oliver Baker Hopkins.

Determination of Nitrogen in Substances Used in Explosives.
W. C. Cope and Guy B. Taylor.

Economic Geology of Gilpin County and Adjacent Parts of
Clear Creek and Boulder Counties, Colorado. Edson S. Bastin
and James M. Hill.

Enrichment of Ore Deposits. William Harvey Emmons.

Fuel Briquetting in 1916. C. E. Leshner.

Lithium Minerals in 1916. Waldemar T. Schaller.

Methods of Testing Natural Gas for Gasoline Content.
G. A. Burrell and G. W. Jones.

Mining Industry in Territory of Alaska during Calendar
Year 1905. Sumner S. Smith.

Motor Gasoline: Properties, Laboratory Methods of Test-
ing, and Practical Specifications. E. W. Dean.

Our Mineral Supplies. J. S. Diller and others.

Oxygen Mine Rescue Apparatus and Physiological Effects
on Users. Yandell Henderson and James W. Paul.

Occurrence and Mitigation of Injurious Dusts in Steel
Works. J. A. Watkins.

Organizing and Conducting Safety Work in Mines. Her-
bert M. Wilson and James R. Fleming.

Physical and Chemical Properties of Gasolines Sold through-
out United States during Calendar Year 1915. W. F. Rittman
and others.

Pine Trees of Rocky Mountain Region. George B. Sud-
worth.

Platinum and Allied Metals in 1916. James M. Hill.

Primary Volatile Products of Carbonization of Coal. Guy
B. Taylor and Horace C. Porter.

Rescue and Recovery Operations in Mines after Fires and
Explosions. James W. Paul and H. M. Wolflin.

Sandstone Quarrying in United States. Oliver Bowles.

Submarine and Kindred Problems. Naval Consulting
Board.

Talc and Soapstone in 1916. J. S. Diller.

Tungsten Minerals and Deposits. Frank L. Hess.

Underground Latrines for Mines. Joseph H. White.

Use of Panoramic Camera in Topographic Surveying, with
Notes on Application of Photogrammetry to Aërial Surveys.
James W. Bagley.

Water-Supply Papers 362, 386, 391, 394, 401, 403, 405,
423, 425-A.

Wet Thiogen Process of Recovering Sulphur from Sulphur
Dioxide in Smelter Gases. A. E. Wells.

Zinc and Cadmium in 1915. C. E. Siebenthal.

Municipal Reports.

Fall River, Mass. Annual Report of Watuppa Water Board for 1916.

Reading, Pa. Annual Report of Bureau of Water for 1915.

LIBRARY COMMITTEE.

NEW ENGINEERING WORK.

(Under this head a brief description of new engineering work contemplated or under construction will be presented each month. Engineers and contractors are requested to send descriptions of their work to the Secretary, 715 Tremont Temple, Boston, before 1st of each month.)

Commonwealth of Massachusetts.—METROPOLITAN WATER AND SEWERAGE BOARD. — *Water Works.* — Work in progress: on portion of 66 000-volt transmission line in Clinton and Berlin.

METROPOLITAN WATER AND SEWERAGE BOARD. — *Sewerage Works.* — Work in progress: Section 98 and Section 102, Wellesley Extension, Deer Island Outfall Sewer.

Work contemplated: Section 101, Wellesley Extension, is advertised. Bids to be opened September 26, 1917.

METROPOLITAN PARK COMMISSION. — The following work is in progress:

Old Colony Parkway. — Construction of a temporary bridge across the Neponset River between Boston and Quincy.

BOSTON TRANSIT COMMISSION. — *Dorchester Tunnel.* — The following work is in progress:

Section F. The interior finish of the station and the construction of a prepayment surface station in Broadway for the interchange of passengers between surface cars and the tunnel.

Section G. Emergency exit at the pump-well, corner of Dorchester Ave. and West 5th St.; construction of bridge over the tracks of the New York, New Haven & Hartford R. R. Co. leading to the docks; ventilating chamber and emergency exit and a section of the arch near the intersection of Dorchester Ave. and Old Colony Ave.

Section J. The interior finish of the station and the construction of a surface station for the interchange of passengers between surface cars and the tunnel.

New York, New Haven & Hartford Railroad. — CONSTRUCTION DEPARTMENT.

South Boston Cut Improvement. — Enlargement of South Boston Cut to Boston Freight Terminal to accommodate four tracks instead of two, and reconstruction of eleven overhead highway bridges so as to span four tracks instead of two, progressing.

Southampton Street Engine Facilities. — New 39-stall engine house, 95-ft. turntable, ash pits, boiler house, office building, and water tank practically completed. Necessary trackage, etc., progressing.

Boston Elevated Railway Company. — BUREAU OF ELEVATED AND SUBWAY CONSTRUCTION. — *Everett Extension.* — The Everett Extension of the Boston Elevated Railway Company, involving the construction of the new bridge across the Mystic River and the reconstruction of the present Malden Bridge, has advanced to the point where the steel structure on either side of the new drawbridge is completed, the railway drawbridge having been completed for about a month or more. The highway draw was put in operation for navigation on September 25; the surface cars, however, were turned over this bridge on July 22, and it has been in service for highway traffic since that time. The old draw just to the south of the new one was closed permanently September 25, and the work of dismantling immediately begun. Beyond the present elevated steel structure now erected, the foundations are completed to the point where the rapid transit lines will reach the surface of the ground, and work is under way on temporary terminal station in Everett.

At the Beacham St. Yard in Charlestown, a new inspection shop is approaching completion. This is a wooden frame structure with wire lath and cement plaster walls. It is approximately 420 ft. long and 60 ft. wide, joining directly on to the northerly end of the present brick inspection shop, which is being altered to accommodate the main line tracks of the proposed Everett Extension, passing through the southeast corner of this building.

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

AVIATION AS APPLIED TO THE NAVY.

By GEORGE D. MURRAY,* LIEUTENANT, U.S.N.

(Presented May 16, 1917.)

I TRUST that in our discussion of some of the problems of aircraft as applied to the navy, I may be able to suggest to your minds certain ideas and thoughts which may help you in studying the various phases of the present war pertaining to naval operations.

As the term "aircraft" does not convey a particularly clear idea to the lay mind, a few definitions should be given, in order to make clear what follows.

(a) "Aircraft," include lighter-than-air machines, such as balloons, air-ships or dirigibles; and heavier-than-air machines, which are termed airplanes.

(b) In the lighter-than-air machines, sustentation is obtained from the buoyancy of a volume of light gas. In the heavier-than-air machines, sustentation is obtained from the dynamic lift of the wings. In both cases, i.e., with lighter-than-air machines and heavier-than-air machines, propulsion through the air is obtained by means of propellers producing thrust sufficient to overcome the resistance of the air.

(c) The airplane when equipped with landing gear (usually wheels), to permit it to rise from the ground and alight on the ground, is commonly called a "land machine"; while the air-

* United States Custom House, Boston, Mass.

plane when equipped with landing gear (usually a float or pontoon system), to permit it to rise from and alight on the water, is generally termed a "seaplane."

To-day the importance of aircraft in land operations both for strategical and tactical purposes is keenly realized by all of us, yet the wonderful feats which are now daily occurrences over the battle fronts of Europe were but the dreams of the most visionary a few years ago. A similar condition as regards the use of aircraft in naval operations does not exist, and except for occasional dispatches reporting demonstrations against seacoast towns, stations or supply depots, little is heard regarding the use of aircraft at sea. Further, on account of the main German fleet remaining inactive, bottled up by the British navy, the development of the strategy and tactics of aircraft in naval operations has not been so marked as has been the case in land operations.

While it may appear to be a slight digression from the subject matter, I shall venture to outline briefly what is meant by naval strategy and tactics, in order that we may establish the relations which aircraft bears to them.

Strategy, briefly, involves all preparation made in anticipation of an engagement before the enemy is sighted; or, in other words, it is limited to planning and directing. It includes the following:

(a) The number of vessels of each type required and their characteristics.

(b) Location of naval bases, repair stations and their capabilities.

(c) War plans providing for all possible contingencies.

(d) Organization of the forces.

(e) Operations and movements of forces in the execution of policy in peace and war.

(f) Operations and movements of forces for the purpose of exercising and test, as in war games.

It can, therefore, be seen that strategy extends back over a long period of time before an engagement with the enemy forces is imminent, and the development of its various phases continues up to the time the fleets make contact.

Tactics, on the other hand, begin where and when strategy finishes, and cover the movements and operations of the forces while in contact with the enemy. In the study of it, not only the strength, possible movement and disposition of one's own forces in an operation must be considered, but also the strength, gun-power, disposition, course, speed and maneuvering qualities of the enemy under various conditions of wind and weather.

It therefore becomes apparent that, in the development of strategy and tactics in naval operations, the employment of aircraft is an important factor, and in the study of strategy and tactics, due consideration must be given to the presence and employment of aircraft in both forces.

It may be stated that the following duties must be performed by naval aircraft: (a) Scouting from ships at sea; (b) off-shore scouting from coastal stations; (c) spotting; (d) offensive operations against enemy aircraft and possibly against ships and stations.

Of the above, it is considered that (a) scouting from ships at sea is of primary importance, and it is the endeavor of the navy to develop seaplanes for this purpose.

In order to provide a seaplane that will most efficiently do the work required, i.e., to scout at sea, we must have one that possesses great speed with as low a landing speed as possible; pontoons or floats which will allow it to withstand rough usage on the water, yet light enough so that good flying qualities are not sacrificed; and of such size as will permit economical stowage aboard ship.

The development of the seaplane has been carried on for several years, and it has still a long way to go before most of the military conditions required to make it fulfill its purpose are attained. The principal reason for this is that the conditions of service that the seaplanes must meet are much harder than for land machines. In detail: first of all, we have greater weight and head resistance, which affect both the climb and the speed possible to attain; second, the difficulties of float or pontoon construction, which are enormous, since weight must be cut down, head resistance diminished, and speed, climb and maneuvering qualities in the air obtained; third, the problem of

stowage aboard ship; fourth, the problem of launching from the deck of a ship, or allowing the seaplane to fly from the surface of the sea; and lastly, the additional engine power required to get the machine off the water.

The solution of the seaplane problem is rendered more difficult because so few people really understand the many difficulties encountered. A certain amount of coeducational work of both manufacturer and user was, therefore, necessary before any real progress could be made.

Before arriving at the type of seaplane that must be used for scouting purposes at sea, many months have been spent in the development of a suitable type of training machine. This type of machine is now fairly well established as compared with other types. It necessarily is slow, with a wide range of speeds, has a reasonable climbing rate, and possesses good control and maneuvering qualities. In general, this type has about the following dimensions: Span, 40 ft.; chord, 6 ft.; gap, 6 ft.; length over all, 27 ft.; height, 10 ft.; area of lifting surface, 450 sq. ft. It is equipped with a 100-horse-power water-cooled motor, and its total weight loaded, meaning weight of the seaplane plus weight of pilot and passenger and oil and gasoline for flight of $2\frac{1}{2}$ -hours' duration, is 2 300 lbs. Its maximum speed is 65 miles an hour, minimum speed 40 miles an hour and climb 2 500 ft. in ten minutes. Now compare these specifications with those of the first speed scout that is about developed. We have, in the latter type, span, 28 ft.; chord, 4 ft. 6 ins.; gap, 5 ft.; length over all, 24 ft.; height, 10 ft.; area of supporting surface, 240 sq. ft. It is equipped with a 100 horse-power water-cooled motor, and its total full load, meaning pilot, oil and gasoline for flight of $2\frac{1}{2}$ hours, is 1 500 lbs. Its maximum speed is 95 miles per hour, minimum speed 50 miles per hour, and climb 5 000 ft. in ten minutes.

In the second duty of naval seacraft, for "off-shore scouting from coastal stations," use will be made of what are termed dirigible Blimp balloons, a type of lighter-than-air craft now under construction. In its development we have been unfortunate, as most of the work has been done abroad (the knowledge on the subject in this country being very limited), resulting in

slow progress being made. The shape of the envelope, or bag, of the Blimp dirigible somewhat resembles that of a cigar. The entire length from tip to tip will be 160 ft. and the maximum diameter 31.5 ft., and the maximum width over the tail fins will be 36.2 ft. This envelope will displace 77 000 cu. ft. Suspended from the envelope will be a rigidly built car, spacious enough to carry a pilot, an observer, the necessary accessories for determining altitude, speed, etc., and a 100 horse-power gasoline motor of the latest improved type. The car used in these dirigibles will closely resemble that of the ordinary airplane, except that it is so constructed that for strategic or other reasons the pilot may light upon a body of water. This is made possible by attaching skids of ash, to which are securely fastened large waterproof cylinders of fabric stuffed with kapok fiber, which afford the requisite buoyancy. Ample room is provided in the car for the pilot and observer as well as the compact power plant, and both compartments are well protected from the weather. The total weight of the dirigible will be about 5 000 lbs. Provision is also made for carrying ballast, which, when thrown out, will enable the dirigible to reach an altitude of 7 500 ft. with safety. These dirigibles are to be so constructed that the maximum speed of 45 miles per hour may be maintained for ten hours. They can also endure sixteen hours of flying at the cruising speed of 35 miles per hour, which permits a range of 560 miles.

The third duty for aircraft to perform is "spotting." While nothing of a very exact nature concerning the employment of aircraft for spotting in the fleet can be told at this time, yet I can say the possibilities of the use of the captive balloon in connection with the spotting of shots in the control of fire are being investigated. In defensive actions, to protect a part of the coast against bombardment by an enemy, the same system of the control of the fire from the coast defense stations, by airplanes, will be used as in all the artillery actions on the European fronts.

To provide for aircraft for "offensive operations against enemy aircraft and possibly against ships and stations," a type of aircraft distinctly different from the scout is required, — one that has real offensive power. The failure of the "Zeppe-

lin " as an offensive arm is pretty generally conceded, and it is beginning to be questioned whether the heavier type of airplane, the battle-plane, mounting guns, is proving much more of a success than the Zeppelin. It is reported that the construction of battle-planes capable of carrying a live load of two guns and the equivalent weight of twenty-odd men has been pretty much abandoned.

Admiral Fiske, in a recently published article, makes some very interesting statements in regard to the battleplane and its employment as a defensive arm in the protection of the coast. He says: " In case our fleet is defeated in the Atlantic during the next year, we shall not have an army that could stand up against any European army that might land on our shores. But if we had a division of, say, one hundred battle-planes near New York, costing about three million dollars, we could certainly prevent disembarkation, transit in boats to the shore and landing of any force of soldiers, especially if the battle-planes were assisted by say, two hundred small aeroplanes, dropping bombs. Similar divisions at other points, including one at the Panama Canal, could perform similar services, and the great speed of the aircraft would enable each division to guard a long extent of coast line. A division of one hundred battle-planes could go from New York to the Capes of the Chesapeake in three or four hours. They could be equipped with 3-inch guns. The muzzle energy of one hundred three-inch guns is equal to the muzzle energy (and, therefore, destructive power) of about sixty thousand soldiers' rifles."

He further states: " That the aeroplane, and especially the battle-plane, will rapidly advance in size and power within the coming year and afterwards, is the mature belief of many aeronauts; should we not, therefore, immediately investigate its capabilities not only as a scout and accessory, but as a major instrument of warfare? "

The training of personnel has been slow, because of the lack of proper aircraft up to a comparatively recent time, with which to carry on the training. The present facilities for training are at the Naval Aeronautic Station at Pensacola, where a great many officers and men are receiving instruction. Since it is

impossible to extend the station much beyond its present capacity, other stations for the training and development of the personnel will be established along the coast. With the present system in efficient operation, it is expected that regular classes of officers and men from the navy, naval militia and coast guard can be qualified for active duty at sea in three months, and civilians with no previous training in six to eight months.

A short discussion of the various qualities and characteristics of the airplane, I hope, may not be considered out of place in closing this paper. The flight of all heavier-than-air machines is based on the following law: "Sustentation is obtained from the dynamic lift of wings, propulsion being provided by means of a propeller producing thrust sufficient to overcome the resistance of the air."

When any thin plane or cambered surface is moved through the air so that its direction of motion makes a small angle with the lower side, the fluid motion of air resulting is unsymmetrical and the resultant pressure of the air is very nearly normal to the plane of the surface. This resultant pressure or "lift" varies according to the angle at which the plane is moved through the air. It increases until a critical angle is reached called the "burble point," when it starts to diminish. On top of a wing, the surface of which is cambered, the flow of air is turbulent and the entire upper surface is under suction. This suction produces a lift which in good wings amounts to more than two thirds of the total lift. Now, in an airplane the total resultant force R expressed in pounds for a velocity V feet per second of an airplane of S square feet area can be stated as follows:

$$R = KiSV^2,$$

where Ki is a coefficient which varies in an irregular manner for different shapes of wings and for different attitudes of the same shape. By "attitude" is meant the angle at which the wing is presented to the wind. This is termed "the angle of incidence" and is arbitrarily defined as the acute angle between the wind direction and the lower chord of the wing section cut by a vertical plane parallel to the wind direction.

Now, if we express the above formula as R equals KSV^2I ,

in which " K ," in this case, represents the coefficient of the form of the wing, and " I " represents the particular angle of incidence, and rewrite the equation as V_2 equals $\frac{R}{KSI}$, we see that the only variable is " I ," the angle of incidence. This means that for every speed of the airplane there is but one angle of incidence. Therefore, in conclusion, we may state that the speed of an airplane depends upon the angle of incidence of the wings, and the horse-power can only affect the speed through the intermediary of the angle of incidence.

DISCUSSION.

MR. CLIFFORD L. WEBSTER.* — When men first started to build aeroplanes, practically every designer or experimenter had some ideas of his own on the best method of control of aeroplanes, so we have had all sorts of means of handling control surfaces. In the main, the control surfaces consisted of the vertical rudder and the horizontal rudder behind, and the ailerons or some method of twisting the wings which is the equivalent of ailerons. One man would prefer to warp his wings by foot-power and steer with a wheel and lift with the same wheel. Another man would prefer to move his ailerons with his hands and to steer with his feet. The Wright brothers worked out a system where with your right hand you pushed a lever forward and back to warp the wings, which was unnatural, working at right angles to the effect you were trying to cause; and with the left hand you had a lever to push forward and back for your up-and-down control, which gave you the two hands working sometimes in opposite directions and sometimes in the same direction, but seldom the same amount. It was something like the stunt of rubbing your stomach and patting your head. Then they gave you a little wrist motion on top of the warping lever to work your rudder with. You could work your warp and rudder together, which was the only advantage of it. The Wrights later turned out a machine in which you worked your ailerons with a wheel and then had a segment which worked the rudder. The Navy rather

* With the Burgess Co. & Curtis, Marblehead, Mass.

approved of that method, but found it was so hard to get the adjustment between the segment and the wheel correct that it was not considered advisable to retain it, and they put the control of the rudder on a foot lever, making it into the "Deperdussin" control, which is practically universal now. There is a wheel to operate the ailerons. You roll the wheel away from the wing which is too low, bringing the wing up. The steering is done by pushing the foot forward on the side to which you wish to turn, just the opposite of the little boy's go-cart. That seems to work very well in connection with the rolling wheel. The wheel is pushed forward to descend and pulled back to ascend.

In training, of which I shall probably do considerable this summer at the Squantum school which has just been opened, the general procedure is to take the pupil up in a two-passenger machine having a set of controls in each seat. On the first flight you simply give him a passenger flight of about fifteen minutes, so he can see how it feels to be in the air and permit him to get over any uncomfortable sensations he may have. On the second flight we tell the pupil to put his hands on the control and feel about the amount and direction in which they operate. Then by the third lesson he has very well in mind what he ought to do, and we let him go ahead and try to do it while the machine is flying at a considerable altitude, allowing plenty of room below, so that if he makes a mistake the instructor has time enough to grab the controls and correct it before they get uncomfortably close to the ground. Then for several lessons we just try him on that, not letting him bank very much, — possibly 15 degrees, — finding out just how much he should turn his rudder for a certain bank, keeping the machine pretty level fore and aft. I think that possibly after a matter of two hours of actual flying, comprising perhaps eight lessons in all, the average pupil has the knack of it pretty well. He can then fly around in the atmosphere well off the ground and feel quite comfortable and not get into trouble. Then we start to get off the water and bring the machine back. That is a little more ticklish work because you have to get down close to things and you find you have to act very quickly. The difference in judg-

ment of a fraction of a second may be the difference between making a good landing and smashing an aeroplane, so then the instructor really sits up and takes notice and has his hands right close to the wheel ready to grab it quickly. The pupil usually bounces the machine around on the water, a good bit in first getting it off. When he gets up he comes coasting down to the water and probably forgets that the water is there, and then the instructor has to pull the machine up before he hits the nose of it. He goes up again and then becomes a little afraid of the water. He coasts down and levels the machine about twenty feet off the water at the time it ought to land, and then the instructor has to get the machine down close to the water before it loses its speed, otherwise it settles with a bump. That is called "pancaking" the machine, which gives you a good idea of what really happens. We try the pupil on getting the machine off the water and on landing it, at the same time improving his ability in driving through the air. This flying is done, of course, in short jumps, flights of about five minutes, getting up and landing again quickly, making a series of jumps, just touching on the water. Then after a matter of possibly five hours of flying the pupil really knows how to fly the machine under good conditions. We send him out when there is a good day, and the instructor hopes he has not neglected to tell him anything. After a few flights the pupil takes his certificate, which means that somebody has seen him make a certain number of figure 8's and land the machine without smashing it within a reasonable distance of a given mark. Also that he has taken the machine up three hundred feet, shut his motor off, and glided down with a dead machine or engine. Of course the dead-engine stunt is given toward the end of the course, because with the engine off you have only one try at landing. If the power is on you can speed up and go on a little farther if necessary. If the engine stops and you get down close to the water, you must land. After the pupil has taken his Aero Club certificate and flown the machine alone, if he is going to do any more flying he starts in and really learns after that. He has just got the idea of it then. He is all right in good weather and under good conditions, but whether he would "get away with it" under unusual conditions,

no one knows, and so the Army and Navy require, before they put him to any serious work, that he should go ahead and fly by himself in various sorts of weather at various altitudes, having certain objects in view, — either cross-country flying, spiraling, circling or something else, — a matter of forty hours, more before they consider him a good pilot. When I speak of hours of flying, that means adding up the total number of short flights. A preliminary course of flying, which is between five and six hours, will probably be extended over a period of a month or six weeks, if it is bad weather.

Q. — How long a lesson do you find a pupil absorbs best?

MR. WEBSTER. — As a general thing, we think a lesson of about twelve to fifteen minutes is best. When a pupil is just starting in, anything over fifteen minutes gets to be quite tiring; so we use rather short flights. Frequently toward the end of the course a pupil will do perfectly well if you keep him going for half or three quarters of an hour, and once a man has learned to drive a machine, he can do so for hours without getting tired at all. It is like learning anything else. At first you grip the wheel like death. When you get used to the control, you can take two fingers and handle it.

Q. — What is the highest speed obtained in this country?

MR. GREELY S. CURTIS.* — I believe the highest speed was that made by a racing monoplane at Chicago some years ago, — about one hundred and twenty miles per hour or thereabouts. There have been some speed scouts built for the Army and Navy, but if they have exceeded that speed, it is still concealed by the censor.

Q. — Do you think flying will ever come into use for utilitarian purposes?

MR. CURTIS. — I took "flying" as the subject of a thesis in 1892; but every year takes off a little from my original anticipations, until now I am somewhat discouraged about its future. It seems less and less likely to develop usefully as each year passes. There are so many risks and there is so much expense. The deterioration of the motor is — I won't say a dollar a minute — but about twenty dollars an hour as a minimum, which is for

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the use of the motor alone, not counting repairs or anything of that kind, and that makes it a very expensive sport.

Q.—What is the cost of a medium-sized machine, such a machine as could be used in flying on land?

MR. CURTIS.—Some of the machines shown on the screen have been built for \$5 000. I do not think there have been any built below that, and they run a long way above. I saw some bids for Navy specifications at \$22 000 for a machine. Those are not the gigantic machines. They are for military purposes. I think the cost is apt to increase rather than decrease.

Q.—Are revolving motors used at all now here?

MR. CURTIS.—The government has quite recently placed an order for, I believe, fifty American-made rotating motors, but it came as a great surprise to us, as manufacturers. We heard they had gone out of favor on this side, and very largely on the other side, with the exception of some French motors. We have not seen any rotating motors in practical use here for a number of years. They are much less popular than they used to be, so that this order for a considerable number of them was a great surprise to us.

Q.—What is the cause of their failure, or why are they not considered as good as a stationary motor?

MR. CURTIS.—The best information we have has been that the motor can only run a limited number of hours before it has to be taken down and cleaned out. There is no lubricant known except castor oil, and that gums them up so badly they need constant taking down to clean them. They are very delicate, and are air cooled. When the Hendee Motor Company undertook to duplicate a Gnome motor, they worked for two or three seasons having an actual sample before them, and found they could not make a machine which would run satisfactorily. A company was established in Washington for making rotary motors, and each time they made a new motor they declared the new one would be better than the last. Finally they induced a foreign government to specify one of these motors in one of our aeroplanes, the sale being contingent upon the whole machine operating properly. We had it out tuning up for two months, the longest flight being, I think, about thirteen minutes,

and it never came down twice for the same reason. This indicates that a rotating motor is a very delicate mechanism. They have the secret in France. Duration records have been made with them and they have been wonderfully successful, but they do have the defects I have pointed out, — the gumming up and the necessity for taking them apart and cleaning them out. We have not been able to build them yet properly. There is also another point against them, and that is that if you are doing cross-country flying in military work you can buy anywhere the ordinary automobile oil, which is sufficiently good for the standard type of European motor, but you cannot find more than a quart of castor oil even at a drug store, and therefore you would be stuck where you landed until you could get a reasonably large supply of castor oil.

Q.—Is the center of gravity of a seaplane considerably lower than that of a landplane?

MR. CURTIS.—It depends somewhat on the individual type of machine. In some types of seaplanes the center of gravity is noticeably lower, and it makes a considerable difference. It throws out a large part of the efficiency of the Dunne principle. You can realize that if your propeller is going to be replaced by the force of gravity, the former must act in a horizontal line through your center of gravity; otherwise a shift in your control surfaces would be necessary. When gravity acts on a glide you have a force exerted along the line passing through that center of gravity. If your propeller is located above your center of gravity, there is going to be a turning moment tending to push your nose down. The minute the propeller stops, your upsetting moment forward is going to be relieved and there would be a tendency to sag back. So in the Dunne type or any other type which is going to have inherent stability, the line of propeller thrust must pass approximately through the location of the center of gravity; otherwise a pitching moment would be set up.

Q.—What is the cause of the extremely rapid deterioration in the motor that you speak about?

MR. CURTIS.—The cost of an aeroplane motor runs anywhere from \$3 000 to \$6 000. Assuming you have a high-power motor at \$6 000, three hundred hours is a pretty long life for

an aeroplane motor in actual flying. It is short for an automobile motor, but the aeroplane motor is cut right down to the limit as far as weight goes, and they do not stand up. Something essential gives way long inside of three hundred hours, as a rule. You cannot count on more than that as the life of a high-grade aeroplane motor. That is largely on account of the fact that they have to be built light, but more particularly because in flying the use of the motor is very different from that in an automobile. In an automobile you run with one quarter of your power for ordinary running, or less than that; but in an aeroplane, you have your throttle pretty nearly wide open most of the time, and clear open a good deal of the time, so that it is being driven pretty near its limit most of its life. Some of these motors are designed to run 2 600 revolutions per minute, though others with direct drive run only 1 300 to 1 400. The practice has come in of gearing down the drive from 1 800 or 2 200 R.P.M. to 1 200 R.P.M. You can imagine running 2 200 revolutions for three hundred hours with a delicate mechanism which has been pared down to the lightest possible weight.

Q. — Is there any trouble with lubricating the machine?

MR. CURTIS. — That has been one of the difficulties that all engine designers have been up against. If the motor begins to miss in an automobile you can go on until you come to a convenient garage, but if it begins to miss in the air, you come right down and do not take any chances unless you are under military orders. Mr. Webster can tell you of his experience with a Canadian officer on the St. Lawrence. The Canadians wanted a certain Burgess machine in a hurry. It was taken up to Lake Champlain, and they started to fly from there to Quebec. He will tell you what happened.

MR. WEBSTER. — We flew from Lake Champlain to the St. Lawrence River, a matter of ninety-odd miles, with considerable side wind, so it took an hour and fifty-five minutes. Something had worked loose, and when we landed we were very short of oil. We put in some more and some gasoline also. Probably one of the bearings had got pretty well out of oil during that time and had started to heat a little. So we went forty-five minutes down the river, covering about sixty miles. This was

in the original Burgess-Dunne machine. Then we began to notice a knocking in the machine, so we landed near shore and tried the engine and decided the knock must be in the crank-shaft or connecting rod bearings. Although I wanted to stop right there, this captain said, "No, we will go right through to Quebec." He had driven an automobile motor with a burned-out connecting rod bearing. He owned the machine, and I was willing to take a chance if he wanted to. We started up and headed down the river ahead of the wind, about ten feet off the water, without power enough to get higher, and once in a while dropping almost on to the water. The engine ran about eighteen minutes more and then the piston slid up into the countersunk portion of the head, the piston became broken squarely in two, and the connecting rod finally jumped right out through the crank case and the engine bed. There was considerable noise aft and we landed and drifted until they towed us ashore.

Q. — Are most of the military planes biplanes?

MR. CURTIS. — Practically all. There are no monoplanes so far as I have heard in use by the United States War or Navy departments. They use them on the other side, but they are in a minority. For almost all work they are using biplanes. The latter have a greater capacity and wider range of speed and are better adapted for military uses than the monoplanes, that is, so far as the experience of this war has indicated.

Q. — What is the advantage of having propellers in front as compared with having them in the rear?

MR. CURTIS. — The propeller in front necessarily implies that your motor is in front. If you are flying over land, it is considered by the authorities safer to have your motor land first rather than behind you, because in case of a rough landing it might otherwise get jarred off and fall on you. That is one of the safety reasons. Also your propeller is working in undisturbed air when it is in front. Another very essential feature is that if your motor is behind you will have to build up a framework to carry your tail surfaces, and that framework offers a very considerable resistance to the air and will slow you down. Consequently the pusher type of machine is several miles slower than the tractor type, using the same wing surfaces and the

same motor. So you gain in efficiency and add somewhat in safety by placing your propeller in front.

PROF. EDWIN B. WILSON.*—The theory of the aeroplane, so far as we know it, has been almost all made in England, owing to the excellent training they give in theoretical mechanics, which is, of course, a sort of specialty in England, and has been since Isaac Newton's time. There are a great many things about theoretical mechanics which are not ordinarily considered "practical," and which are not yet taught very much in this country, although the theory of the aeroplane will probably soon demonstrate that they must be more widely taught.

In the early days of the theory of the aeroplane there were quite a number of papers written in France, involving some little trigonometry or something like that, but nothing very complicated or that got very far on the dynamical problem of motions. So far as statics of the aeroplane are concerned, they did very well, but the great question in the theory of the aeroplane is not the statical feature, but the dynamic stability. There is a difference, of course, between dynamic stability and static stability. Dynamic stability is illustrated very well in that Dunne type. If the machine is moving and gets off a steady condition of flight, it tends to come back of itself to that steady condition. A machine may be statically stable and not so dynamically. That is to say, if it gets off its path when at rest, and there is a righting movement tending to bring it back, it is statically stable, but the righting moments may not operate in detail on a moving machine just as they seem to when examined on the machine at rest.

We therefore have to consider the machine as moving in a uniform line parallel ordinarily to the surface of the earth. If slightly disturbed from that, the machine takes up of itself an oscillatory motion, and if the machine is dynamically stable, the oscillation will die out; if the machine is not dynamically stable, the oscillation will not die out. It is not absolutely essential that you should have dynamic stability, but you must not have too serious a degree of dynamic instability or there will be trouble. For instance, the Curtis tractor JN-2 is slightly

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unstable. If it gets off its path it will not come back, but it does not diverge very rapidly so that it is sufficiently stable for practical purposes.

The mathematical theory is entirely a theory of approximations. There is no way of taking into account the motion of the machine in flight under complicated conditions. For instance, I have tried for three years to tell how a machine goes around the loop. I waste twenty-five or thirty hours every now and then, and finally I give it up again. That is just on account of the complication of the problem. Those things which we can handle are relatively simple things, such as the effect on the machine of meeting a stratum of air in which conditions are slightly different from the one in which the machine has been flying. We can thus take some account of the effect of gusts on machines.

The great advances which must have been made in England since the beginning of the war are absolutely unknown in this country. I wrote to Mr. Bairstow, who is at the National Physical Laboratory in England, and asked him if there was any way I could get any information as to what they had accomplished since the war began, because I wanted to use it in my courses at the Institute. He said he would trust me with it, but could not send it on account of the censor, who would not let him send the information or allow him to write about it. The censors have let out a few articles by Professor Bryan in Wales. He has treated of motion in circular flight. The censors let that out. I suppose that is the same as saying the information is not of much immediate practical use. I cannot imagine any other interpretation. But there is the problem, that of circular flight, — one of the most common maneuvers. There is not in print anywhere a practical account of what the aeroplane does in a circular flight, — what different kinds of balance must be had. Engineers can guess at it, and pilots can put the machine through the maneuvers, but whether a machine which is theoretically stable on a horizontal flight remains so for circular flight is not yet worked out properly.

We are all waiting to get some information from England in order to improve our own knowledge and our courses an aero-

plane theory. I suppose they have done some things in France, but before the war we got nothing much except trigonometry out of France. The English were the ones who started it, Professor Bryan in England being the real pioneer, helped by Mr. Harper, who has since been killed in the flying service. There have been, I think, some articles published in Russia, but Russian literature does not get into this country very much, so that, as I say, we are dependent on the accounts of the British government in the annual reports of the National Advisory Committee, and as those stopped coming out two or three years ago, we theorists are all in the dark. Meanwhile our engineers are going on making great progress, as they generally do, away ahead of the theory.

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PAPERS AND DISCUSSIONS

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DIAGRAMS FOR CONTINUOUS BEAMS OF UNEQUAL SPANS.

BY FRANK S. BAILEY,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

It is well known that shears and bending moments in continuous beams of several spans vary considerably from those in simple beams of one span, and diagrams showing shears and bending moments for continuous beams of equal spans are to be found in various textbooks. It not infrequently happens, however, that the architectural designs for a building call for continuous beams of unequal spans, and very little data are to be found showing the shears and moments for such cases.

The maximum positive bending moment in a uniformly loaded simple beam occurs at the center of the span, and this is approximately true of continuous beams of equal spans. In continuous beams of equal spans, a negative moment exists over the intermediate supports, and, if the end spans are fixed, at the end supports as well.

With uniformly loaded continuous beams of unequal spans, the above statements do not hold true; in fact, it sometimes happens that a positive moment occurs over a support and a negative moment at the center of the span. Furthermore, in

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the case of equal spans, the negative moment seldom extends to more than one fifth or one fourth the length of span from the support, and reinforcing steel in the top of the beam, to provide for negative moment, is not required for more than this distance from the support, i.e., one fifth to one fourth the span length. With unequal spans, however, the negative moment may extend over the whole span length, and steel is needed in the top of the beam for its entire span. Also in regard to the reactions at the supports: with two equal spans with supported ends the reaction at the middle support is five eighths, or 62.5 per cent., the whole load on both spans, but with two unequal spans (such as shown in Fig. 2A), the reaction at the central support is about 69 per cent. of the whole load. It is useful to know such a fact, especially when girders are used for the support of continuous beams.

It is evident, therefore, that diagrams showing shears and moments for several common cases of unequal spans with uniform loads per linear foot should be of considerable value to structural engineers, and a few such diagrams are here shown. They were prepared only after a search of the literature of the subject failed to disclose the desired information. They were computed from the formulas of the "three-moment theorem" which was originally derived by Clapeyron, demonstrations of which may be found in Lanza's "Applied Mechanics," Church's "Mechanics of Engineering," Merriman and Jacoby's "Roof and Bridges," and other treatises to which reference may be made for more complete data.

A brief description of the diagrams follows:

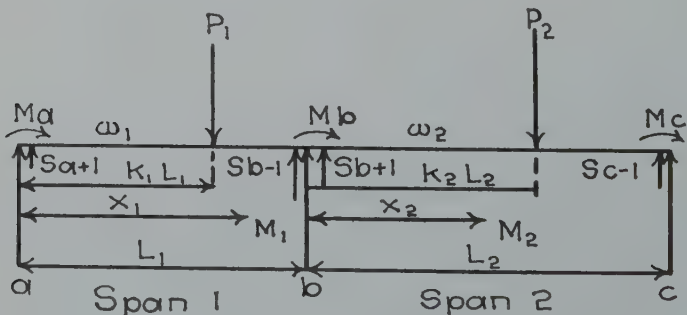


FIG. 1. CONTINUOUS BEAMS WITH UNEQUAL SPANS.

$$MaL_1 + 2Mb(L_1 + L_2) + McL_2 =$$

$$-\frac{L_1^3 w_1}{4} - \frac{L_2^3 w_2}{4} - P_1 L_1^2 (k_1 - k_1^3) - P_2 L_2^2 (2k_2 - 3k_2^2 + k_2^3).$$

$$Sa + I = \frac{Mb - Ma + \frac{w_1 L_1^2}{2} + P_1 (1 - k_1) L_1}{L_1}.$$

$$Sb - I = \frac{Ma - Mb + \frac{w_1 L_1^2}{2} + P_1 (k_1 L_1)}{L_1}.$$

$$Sb + I = \frac{Mc - Mb + \frac{w_2 L_2^2}{2} + P_2 (1 - k_2) L_2}{L_2}.$$

$$Sc - I = \frac{Mb - Mc + \frac{w_2 L_2^2}{2} + P_2 (k_2 L_2)}{L_2}.$$

$$M_1 = Mb + (Sb - I)(L_1 - x_1) - w_1 \frac{(L_1 - x_1)^2}{2}.$$

$$M_1 = Ma + (Sa + I)x_1 - \frac{w_1 x_1^2}{2} - P_1 (x_1 - k_1 L_1).$$

$$M_2 = Mb + (Sb + I)x_2 - \frac{w_2 x_2^2}{2}.$$

$$M_2 = Mc + (Sc - I)(L_2 - x_2) - w_2 \frac{(L_2 - x_2)^2}{2} - P_2 (k_2 L_2 - x_2).$$

$\left. \begin{matrix} Ma \\ Mb \\ Mc \end{matrix} \right\}$ = Moments upon beam at three adjoining supports.

$Sa + I$ = Shear at infinitesimal distance to right of support at a .

$Sb - I$ = Shear at infinitesimal distance to left of support at b .

$Sb + I$ = Shear at infinitesimal distance to right of support at b .

$Sc - I$ = Shear, etc.

w_1 and w_2 = Uniform loads per foot on Spans 1 and 2.

P_1 and P_2 = Concentrated loads on Spans 1 and 2.

$k_1 L_1$ and $k_2 L_2$ = Distances from supports to concentrated loads.

M_1 = Moment at section in Span 1 at distance x from support.

M_2 = Moment at section in Span 2 at distance x_2 from support.

NOTE. If $k_1 L_1$ is greater than x_1 the expression for M_1 changes to $M_1 = Mb + Sb - I(L_1 - x_1) - w_1 \frac{(L_1 - x_1)^2}{2} - P_1 (k_1 L_1 - x_1)$; a corresponding change occurs in M_2 if x_2 is greater than $k_2 L_2$.

Fig. 1 shows the meaning of the various symbols in the formulas.

P_1 and P_2 represent concentrated loads, and are given so that other conditions of loading besides that shown in the diagrams may be investigated. They were not used in calculations for the diagrams, which are based on uniform loading alone. In calculations for uniform loading only, P_1 and P_2 each equal zero, and the terms in which they are present of course become zero. Tables giving the values of the terms $k_1 - k_1^3$ and $2k_2 - 3k_2^2 + k_2^3$ are given in Vol. 4 of Merriman and Jacoby's "Roofs and Bridges" and in Vol. 2 of Hool's "Reinforced Concrete Construction."

Fig. 2A shows shears and moments for two spans, one of which is half as long as the other, with ends supported. In this case it is seen that a negative moment exists over three fourths the length of the shorter span measured from the central support. Steel reinforcement in the top of a concrete beam should, therefore, extend at least this distance. This is the case previously referred to where the reaction at the central support (which is the sum of the shears immediately to the right and left of the support) amounts to 69 per cent. of the whole load on both spans. The high negative moment $\left(\frac{wL_1^2}{2.7}\right)$ in the short span at the central support is an important feature.

Fig. 2B shows two spans, one of which is half the length of the other, with fixed ends. Ends are considered fixed when they are monolithic, with heavy walls or columns. A peculiarity of the case shown in Fig. 2B is that the bending moment at the end of the short span is zero. Generally, where the ends are fixed, a negative moment exists over the end support. The occurrence of a zero moment at the end in this case is due to using span lengths of the particular ratio shown. In the case of three spans shown in Fig. 3, if each of the end spans were made slightly more than one half the length of middle one, a ratio of length could also be found where there would be a zero moment for the ends of the fixed spans.

Fig. 3 shows the curves for three spans, each of the end spans being half the length of the middle span. In this case

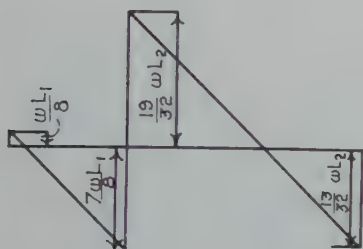
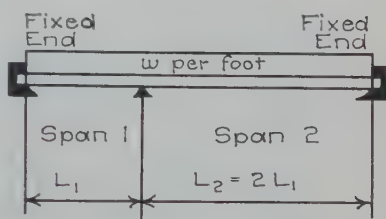
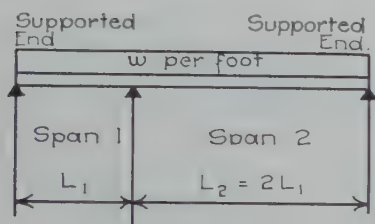
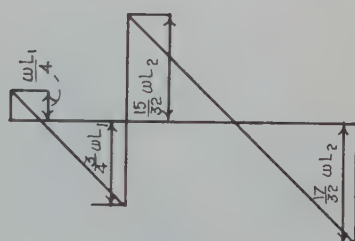
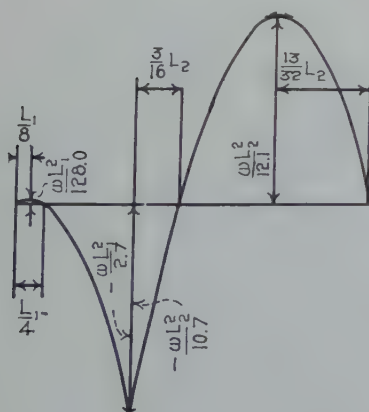
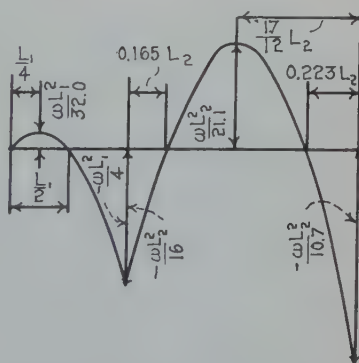
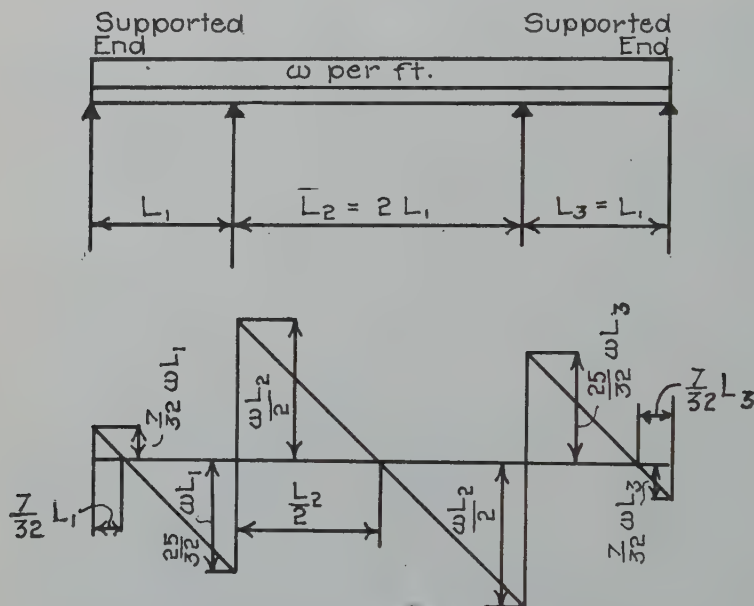

 Curve of shears for uniform load $= w$ per foot over both spans.

 Curve of shears for uniform load $= w$ per foot over both spans.

 Curve of moments for uniform load $= w$ per foot over both spans.

 Curve of moments for uniform load $= w$ per foot over both spans.

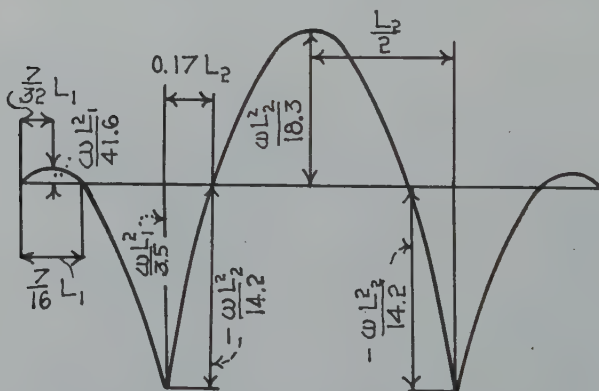
FIG. 2A.

FIG. 2B.

UNIFORMLY LOADED CONTINUOUS BEAMS WITH UNEQUAL SPANS.



Curve of shears for uniform load = w per foot over three spans.



Curve of moments for uniform load = w per foot over three spans.

NOTE. With span lengths as shown in this case, and with uniform load, the shear and moment curves for fixed ends are practically the same as for supported ends.

FIG. 3. UNIFORMLY LOADED CONTINUOUS BEAMS WITH UNEQUAL SPANS.

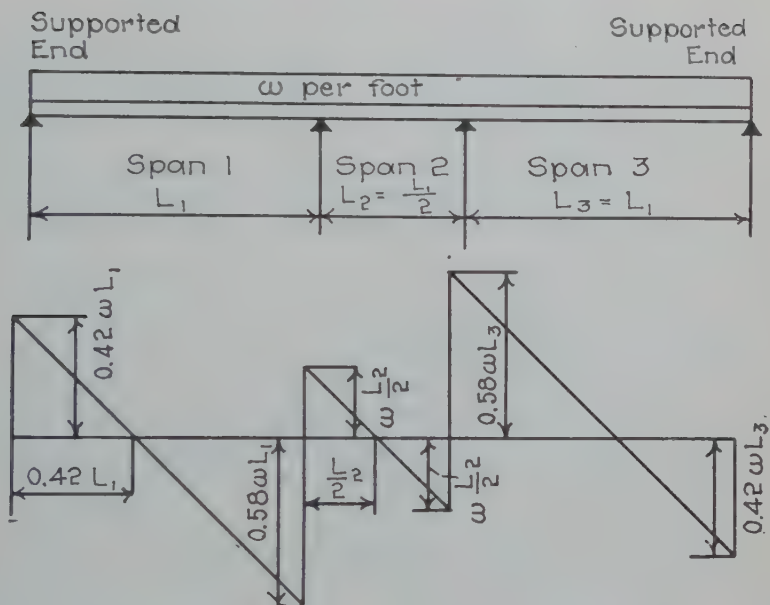
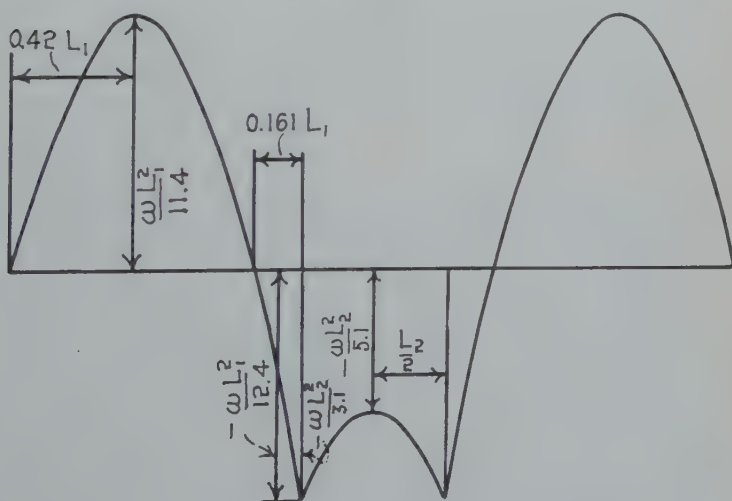

 Curve of shears for uniform load = w per foot over three spans.

 Curve of moments for uniform load = w per foot over three spans.

FIG. 4. UNIFORMLY LOADED CONTINUOUS BEAMS WITH UNEQUAL SPANS.

it is noted that the curves for fixed ends are almost identically the same as for supported ends. As a matter of fact, it was found that a small positive moment existed over the end supports where the ends were fixed.

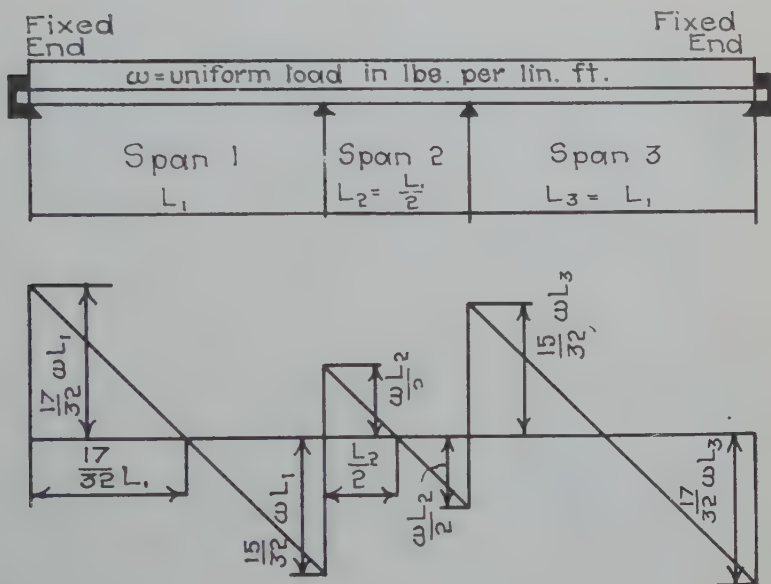
Fig. 4 shows curves for three spans with supported ends, with each of the end spans twice the length of the middle span. It is especially interesting as a case in which there is no positive moment in the middle span, — a negative moment of $\frac{wL^2}{5.1}$ existing at the center of the span. In this case it is evident that the top of the beam should be reinforced with steel for its entire length to provide for the negative moment.

Fig. 5 shows the same span arrangement as Fig. 4 but with fixed ends; the same phenomenon with regard to negative moment occurs in the middle span as was observed in Fig. 4, but to a less amount.

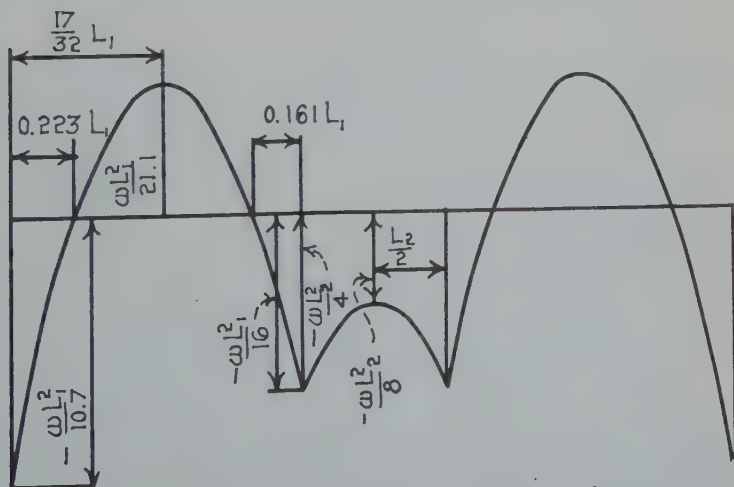
Nearly all authorities recommend using $\frac{wL^2}{12}$ for moment at center and support for interior spans and $\frac{wL^2}{10}$ for center and support for end spans, and perhaps the most striking feature of the diagrams is the information they give as to the high negative moments at the support (and in some cases throughout the entire length of the short span), amounting in one extreme case to $\frac{wL^2}{2.7}$.

In practice this does not affect the design so much as these figures would appear to indicate, for the steel in the top of the beam over the support is, or should be, proportioned to the negative moment for the longer span, and this amount is extended into the short span, thus giving a sufficient amount of steel for the moment in the short span, provided it is extended far enough.

Fig. 6 shows shears and moments for a beam with fixed ends and triangular loading. Mr. W. W. Clifford, member of Boston Society of Civil Engineers, became interested in this problem, and after finding several different solutions which did not agree he enlisted the writer's efforts. To Mr. Clifford belongs the credit for first finding the correct solution. The

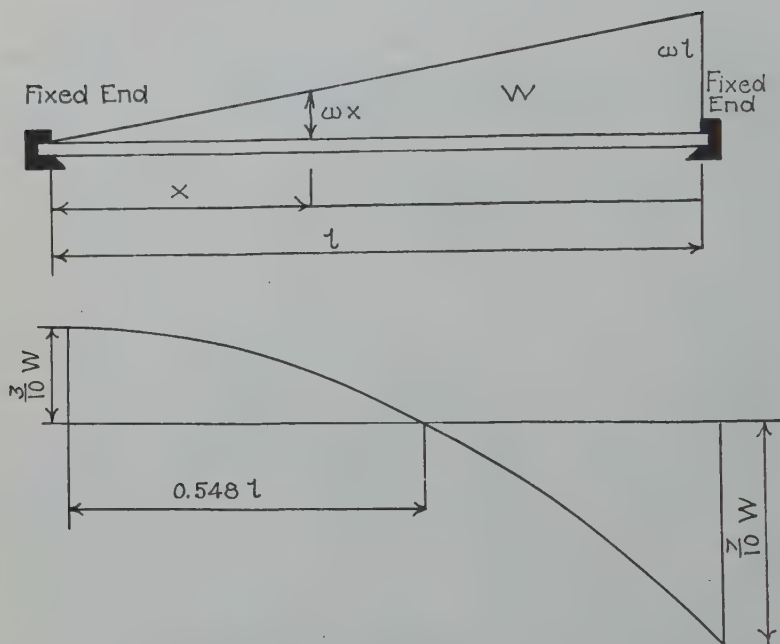


Curve of shears for uniform load = w per foot over three spans.

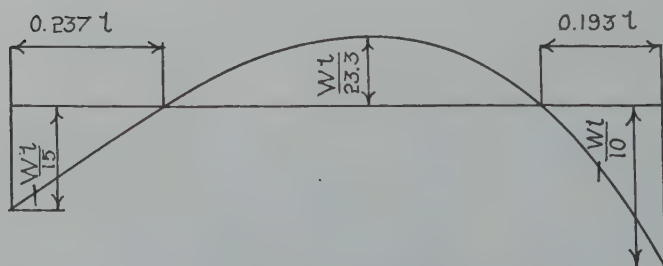


Curve of moments for uniform load = w per foot over three spans.

FIG. 5. UNIFORMLY LOADED CONTINUOUS BEAMS WITH UNEQUAL SPANS.



Curve of shears for triangular load = $w x$ per foot.



Curve of moments for triangular load = $w x$ per foot.

FIG. 6. . TRIANGULAR LOADED BEAM WITH FIXED ENDS.

method he used was to take Merriman's factors $(k - k^3)$ and $(2k - 3k^2 + k^3)$ and with $kl = x$ then assume that a concentrated load $w x$ was applied over each infinitesimal portion of the total length of the beam. The integration gave the follow-

ing equation: $M_1l_1 + 2M_2(l_1 + l_2) + M_3l_3 = -\frac{2}{15}w_1l_1^4 - \frac{7}{60}w_2l_2^4$. The writer checked this result both by Mr. Clifford's method and by following the method given in Lanza's "Applied Mechanics." (See Appendix.)

NOTE.* In actual design for uniform loading, the formulas $\frac{WL}{10}$ for end span and $\frac{WL}{12}$ for interior spans should be used for positive moments, and $-\frac{WL}{10}$ over end supports and $-\frac{WL}{12}$ for interior supports, except where the diagrams indicate the existence of larger negative moments.

In Fig. 3 the bending moment at the wall column is zero, which is caused by the fact that the negative bending moment in the end span, due to the fixity, is taken up by the positive bending moment caused by the loads in the interior span. If the interior panel is not loaded of course the negative bending moment will occur at the wall support and, therefore, must be provided for.

The curves show the theoretical bending moments.

The actual bending moments will be different because not

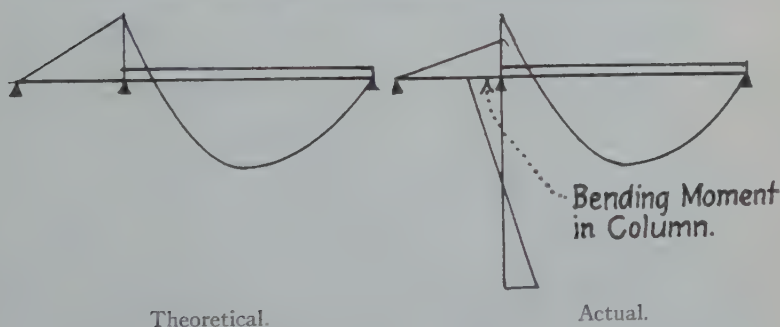
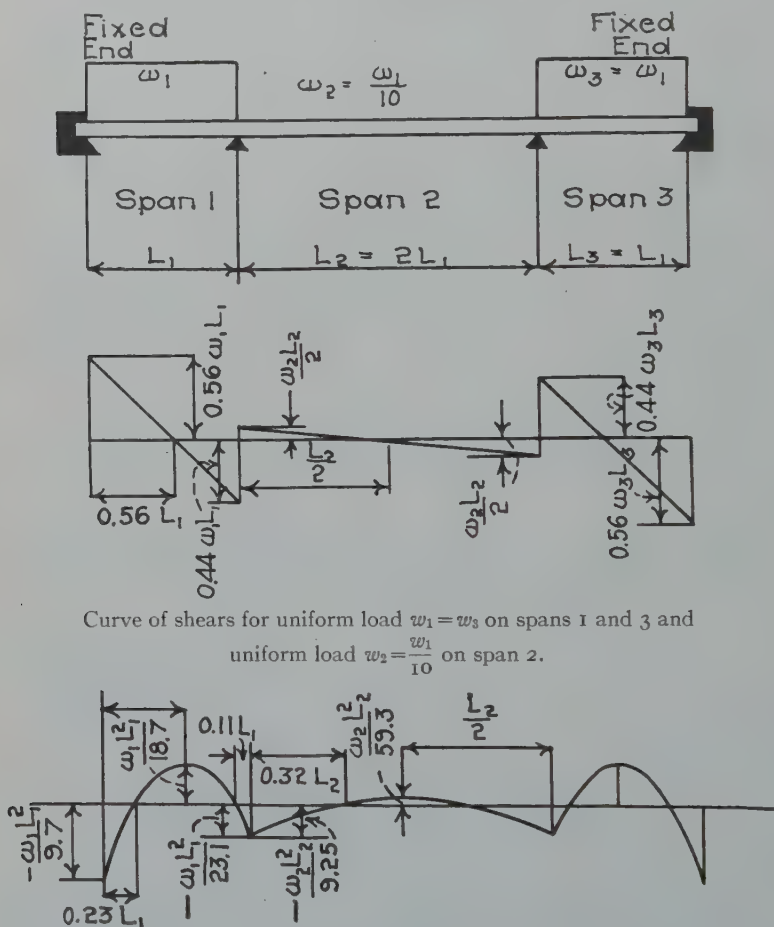


FIG. 7. THEORETICAL AND ACTUAL BENDING MOMENTS.

* The above note is appended at the suggestion of Mr. Sanford E. Thompson. Mr. Thompson's article, "Design and Construction of the Massachusetts Institute of Technology," in the *Journal American Concrete Institute*, July, 1915, contains some useful data on the subject. It was unknown to the writer until some time after this article was prepared. The article, "Design of Wall Columns and End Beams," by Edward Smulski, which is in the same number of the *Journal* referred to, is also of interest.

all of the bending moment is transferred from one span to the other, a good deal being taken up by the column. The effect of one span upon another, therefore, in actual construction, is not as pronounced as would appear from the theory. The sketch (Fig. 7) shows approximately the difference between the theoretical and actual bending moments.



Curve of shears for uniform load $w_1 = w_3$ on spans 1 and 3 and uniform load $w_2 = \frac{w_1}{10}$ on span 2.

Curve of moments for uniform load $w_1 = w_3$ over spans 1 and 3 and uniform load $w_2 = \frac{w_1}{10}$ on span 2.

FIG. 8.

Fig. 8 was prepared to show the effect mentioned by Mr. Thompson of having a light load on the middle span. Comparing it with Fig. 3, it is seen that when the uniform load per foot on the middle span is one tenth of the load per foot on the end spans, there is a very great change in the shears and bending moments in the end spans, the most noticeable features being the great increase in the shear and negative bending moment at the end supports.

APPENDIX.

By first method. Taking two spans of equal length with equal triangular loading beginning at zero at the left of each span and increasing uniformly to a maximum at the right of each span, then, for a single concentrated load—

$$M_3 l_1 + 2M_b(l_1 + l_2) + M_c l_2 = -Pl_1^2(k_1 - k_1^3) - Pl_2^2(2k_2 - 3k_2^2 + k_2^3).$$

As $kl = x$ and there is assumed to be an infinite number of concentrated loads each equaling wx over the whole length, the above equation becomes

$$\begin{aligned} M_a l_1 + \text{etc.} &= -w \int_0^{l_1} \left(k_1 l_1^2 x_1 - \frac{k_1^3 l_1^3 x_1}{l_1} \right) dx - \\ &\quad w \int_0^{l_2} \left(\frac{2k_2 l_2^3 x_2}{l_2} - \frac{3k_2^2 l_2^3 x_2}{l_2} + \frac{k_2^3 l_2^3 x_2}{l_2} \right) dx. \\ &= -\frac{w}{l_1} \left[\frac{l_1^2 x^3}{3} - \frac{x_1^5}{5} \right]_0^{l_1} - \frac{w}{l_2} \left[\frac{2l_2^2 x_2^3}{3} - \frac{3l_2 x_2^4}{4} + \frac{x_2^5}{5} \right]_0^{l_2} \\ &= -\frac{2wl_1^4}{15} - \frac{7}{60} wl_2^4. \end{aligned}$$

By second method, using Lanza's notation—

$$\begin{aligned} m_1 &= \frac{wl_1^3}{6} & m_{-1} &= \frac{wl_{-1}^3}{3} \\ n_1 &= \frac{l_1^2}{2EI} & n_{-1} &= \frac{l_{-1}^2}{2EI} \\ q_1 &= \frac{l_1^3}{6EI} & q_{-1} &= \frac{l_{-1}^3}{6EI} \\ V_1 &= \frac{wl_1^5}{120EI} & V_{-1} &= \frac{wl_{-1}^5}{30EI} \\ M_2 \left(\frac{l_1}{6EI} - \frac{l_1}{2EI} \right) - M_3 \frac{l_1}{6EI} - \frac{wl_1^4}{36EI} + \frac{wl_1^4}{120EI} + M_2 \left(\frac{l_1}{6EI} - \frac{l_1}{2EI} \right) \\ &\quad - M_1 \frac{l_1}{6EI} - \frac{wl_1^4}{18EI} + \frac{wl_1^4}{30EI} = 0; \end{aligned}$$

therefore

$$-M_2 \frac{(l_1 + l_2) 120}{360} - \frac{M_3 l_1 60}{360} - \frac{M_1 l_2 60}{360} - \frac{7wl_1^4}{360} - \frac{8wl_2^4}{360} = 0;$$

and

$$M_1 l_2 + 2M_2(l_1 + l_2) + M_3 l_1 = -\frac{8wl_2^4}{60} - \frac{7wl_1^4}{60} = 0.$$

In this method the expression for unit load is $w(l_1 - x)$ for the first span and wx for the second span. The expression for m is

$$\int_0^x \int_0^x w(l_1 - x) dx^2 \text{ or } \frac{l_1 x^2}{2} - \frac{x^3}{3} \text{ for the first span and}$$

$$\int_0^x \int_0^x wx dx^2 \text{ or } \frac{x^3}{6} \text{ for the second span. The expression for}$$

$$V_1 = \int_0^{l_1} \int_0^x \frac{m dx^2}{EI}, \text{ therefore, becomes } \frac{wl_1^5}{30EI} \text{ for the first span,}$$

$$\text{and } V_2 = \int_0^{l_2} \int_0^x \frac{m dx^2}{EI} \text{ becomes } \frac{wl_2^5}{120EI} \text{ for the second span.}$$

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

CLASSIFICATION OF CIVIL ENGINEERS UNDER THE
CIVIL SERVICE RULES.

REPORT OF THE COMMITTEE.*

TO THE BOARD OF GOVERNMENT,
BOSTON SOCIETY OF CIVIL ENGINEERS:

Gentlemen,—The special committee on Civil Service of the Boston Society of Civil Engineers, appointed at the request of the chief examiner of the Massachusetts Civil Service Commission, in accordance with the vote of the Society on October 18, 1916, begs leave to submit the following report.

PURPOSE OF THE COMMITTEE.

The chief examiner, in his letter requesting the coöperation of the Society, stated:

"The Commission would be pleased to have your Society appoint a committee to go into the question of the classification of civil engineers, as it exists at present under Civil Service rules, to suggest such modifications and changes as would make for the maximum of practicability, simplicity and, in a word, adequacy."

It was apparent that this was an opportunity for the Society to be of service both to the state and to the engineering profession.

* At a meeting of the Board of Government, held September 19, 1917, this report was accepted and the Secretary was directed to forward the same to the Civil Service Commission.

WORK OF THE COMMITTEE.

As the state Civil Service examinations for engineering positions are usually held annually in December, and as changes in the Civil Service rules must receive the approval of the Governor and Council and be published at least sixty days before going into effect, it was not possible for the Society to take any action which would have become effective at the examinations last December. Accordingly, the committee has deemed it wise to take ample time for mature consideration of the subject, with a view to presenting its report in season to have its recommendations, if accepted by your Board and by the state authorities, take effect prior to the holding of the engineering examinations in December next.

Seven meetings have been held, the first on November 28, 1916, and the last on the date of this report.

The first meeting was a conference between the committee and the chief examiner and the special civil engineer examiners of the Civil Service Commission; at this conference the committee was enlightened as to the present rules and regulations governing engineers in the classified service of the Commonwealth and its municipalities, and as to difficulties experienced under the present system.

At the second meeting, on December 12, the views of engineering employees within the Civil Service were presented by representatives of the Public Service Engineers' Association of Massachusetts, an organization including about three hundred civil engineers in state and municipal employment.

At the third meeting, on February 13, 1917, representative heads of state and municipal engineering departments were present, and expressed their views regarding the workings of the present Civil Service rules and regulations and made valuable suggestions for modifications of the same.

Through the chief examiner the committee was supplied with voluminous data consisting of copies of rules and regulations, annual and special reports and typical examination papers relating not only to Civil Service work in this Commonwealth, but also to that in the states of New York, Illinois, Wisconsin and California, and the cities of New York, Philadelphia

and Chicago. Particular attention has been given to the report made to the Massachusetts legislature in January, 1916, by the Commission on Economy and Efficiency concerning the standardization of grades and compensation in the civil engineering service of the Commonwealth, as proposed in House Bill No. 349 of 1915 (House Doc. No. 1673 of 1916).

The fourth and subsequent meetings of the committee have been devoted to consideration of the information and the data thus obtained, to further conferences with the chief examiner and with the special examiners, and to the preparation of this report.

FAULTS OF THE PRESENT SYSTEM.

The provisions of the Civil Service were extended to cover civil engineers in municipal service on February 15, 1897, and in state service on March 1, 1902. The present regulations governing this service became effective in March, 1912. While much may be said in commendation of the inclusion within the Civil Service of the engineering forces of state and municipal departments and of the benefits that have since been gained, it is apparent to your committee that the system has not yet reached its maximum of usefulness, and that it has often failed, in competition with private employment, to attract or to retain engineers of thorough training and wide experience.

The committee believes that unless something is done to make this public service more attractive to graduates of technical schools and to engineers of proven ability, there is a danger that the personnel of the engineering staffs in the public service in this state will, as a whole, fall backward, rather than advance.

Some of the faults of the present system which your committee believes should be remedied are specifically as follows:

1. *Provisional Appointee.* "Present Civil Service regulations allow of provisional appointments, and these appointees, if employed continuously for one year, are rated as permanent and are not required to take examinations." (House Doc. No. 1673 of 1916, p. 6.) It appears that under Rule 6, Class 27, of the existing Civil Service rules, a rodman may be provisionally appointed at a salary slightly in excess of \$300 a year, for the

reason that no one who has passed the rodman's examination and whose name is on the eligible list is willing to accept a position at the salary offered. If rated as permanent after a year's provisional service, it is possible for this rodman to be advanced in rating and pay until his salary reaches the maximum figure of \$1 500 per year, *without any examination whatever*. The door is thus opened to the appointment to the engineering service of persons without engineering training of any sort, and they may remain in the service without examination until they reach a compensation and position which should carry some degree of engineering responsibility.

2. *Certifications for Municipal Appointment from Local Lists Only.* Although the Civil Service is a state-wide institution, there is, in addition to the state eligible list, a local eligible list for each municipality. If the appointing officer in any city desires to make an appointment, names are certified by the Civil Service Commission from the local list, if, and to such an extent as, names may be available thereon. In the case of engineering positions in cities outside of Boston, — and occasionally this is true for Boston itself, — it is a common occurrence either that there will be no local eligible list or that the list will be insufficient to supply the requisite number of names to give the appointing officer his choice in appointment. In such a case it sometimes happens that the appointing officer will request that names be certified from the state list, which is permissible, but more often the appointing officer exercises his right of provisional appointment from outside the list. In cities outside of Boston, it is seldom that an appointment to a higher engineering position is made from the Civil Service list, because the local list is inadequate to supply the demand.

3. *Credit Allowed for Experience.* At present too little weight is given to the experience of an applicant who takes the engineering examinations. Under the present rules, in the case of rodmen and instrumentmen, experience is marked on a basis of .5 points out of a total of 16 points or 31 per cent. of the total rating, while for junior and senior assistant engineers experience is weighted at only 5 points out of a total of 18 points, or only 28 per cent. of the total mark. It will thus be seen that actually

less credit is given for experience in the higher grades than in the lower. Your committee believes that the higher the grade the greater should be the weight given for experience, and that the present system does not fairly rate engineering applicants in the higher grades.

The committee believes that where so large a proportion of the total mark is based on the result of written examinations, there is a tendency for young engineers, fresh from school, to be given too high a rating, while older and more experienced engineers, more or less rusty on book knowledge, may be given too low a rating. The low weight given to experience as compared with the high weight assigned to written examinations is doubtless a factor which deters older engineers with considerable experience from taking the Civil Service examination. In other words, the present rule in this particular is not one which tends to secure the best men.

4. *Dropping of Names from Eligible List.* At present, "No person shall remain eligible for more than two years upon any eligible list unless the Commission shall by vote continue the eligibility beyond said period" (Rule 18, Section 3). So far as engineering positions are concerned, your committee is agreed that the interests of the service will be advanced if engineers are retained on the eligible list for a substantially longer period than two years.

5. *Specialists in Engineering Work.* Testimony has been presented to the committee which would indicate that in past years the Civil Service Commission has at times failed to appreciate the degree of specialization in the higher grades of engineering work, and has certified names of engineers for the higher positions for which their training and experience have not specially qualified them, to the exclusion of engineers lower down on the list whose special training has been along the lines in question. It is believed, however, that the need of engineering specialists is generally recognized by the Commission at the present time, and that this fault has been largely, or wholly, rectified.

6. *Investigation of Applicants for Examination.* The examining force of the Civil Service Commission, as at present

constituted, is inadequate properly to follow up and investigate the experience sheets of applicants for examination for engineering positions. The chief examiner is to be congratulated upon the work which he is doing in this direction with the very limited means at his disposal.

7. *Standardization of Salaries.* A fault of the present system, according to the testimony of representatives of the engineering employees, is the lack of standardization in salaries of engineering positions in both the state and municipal departments. After careful consideration, your committee has decided that inasmuch as this is a matter which doubtless can only become effective through legislative action, and as the work of your committee is limited to a consideration of the Civil Service rules and regulations which may be modified by the Civil Service Commission with the consent of the Governor and Council, it is not within the committee's province, or desirable at this time, to undertake the study of the standardization of engineering salaries in state and municipal departments.

RECOMMENDATIONS.

The committee recommends that such modifications of the present Civil Service rules and regulations be made as may be necessary to conform to the following recommendations:

1. *Classification.* The present classifications, especially as regards rodmen and instrumentmen, seem confusing and unsatisfactory. The classifications along the lines formerly in force appear preferable. The following grades for engineers and for draftsmen are recommended:

Grade A. Rodmen with pay up to \$900, inclusive.

Grade B. Instrumentmen with pay over \$900 and not exceeding \$1 400.

Grade C. Junior assistant engineers with pay over \$1 400 and not exceeding \$1 900.

Grade D. Senior assistant engineers with pay over \$1 900.

Grade E. Junior draftsmen with pay up to \$900, inclusive.

Grade F. Senior draftsmen with pay over \$900 and not exceeding \$1 600.

Should the above classifications and pay rates be adopted by the Civil Service Commission, provision should be made that those now serving in grades corresponding to the new grades above named but with salaries in excess of the proposed new upper limit in each case shall automatically be placed in the grade corresponding with the salary which they now receive.

2. *Qualifications for Examination and for Promotion.* The qualifications required for original examination and for promotion should be identical and as follows:

(a) For Grade A (rodman) or Grade E (junior draftsman), at least one year's good practical experience; or (2) the successful completion of one year's study at a school of engineering of recognized reputation authorized by law to confer degrees.

(b) For Grade B (instrumentman) or Grade F (senior draftsman) at least three years' good practical experience; or (2) graduation from a school of engineering of recognized reputation authorized by law to confer degrees, plus one year's good practical experience; or (3) the successful completion of two years' study at such a school, plus two years of good practical experience.

(c) For Grade C (junior assistant engineer) five years' good practical experience; or (2) graduation from a school of engineering of recognized reputation authorized by law to confer degrees, plus two years' good practical experience.

(d) Grade D (senior assistant engineer) at least eight years' good practical experience; or (2) graduation from a school of engineering of recognized reputation authorized by law to confer degrees, plus four years of good practical experience.

3. *Experience Sheet.* Every applicant for examination for any engineering position should, as at present, file with the Commission an experience sheet according to a form furnished by the Commission, which experience sheet should be sworn to.

The experience sheet should be filled out in minute detail, especially in the case of applicants for examination for the higher positions, and in all cases should be in such form as to determine the applicant's experience as fully as possible. It is believed that the Civil Service forms should properly be revised and amplified. Each experience sheet should contain a list of references and also a complete list of former employers.

4. *Investigation of Experience Sheet.* The applicant's statements in his experience sheet should be carefully verified, and if possible further information obtained as to his ability, character, habits and personality by communication not only with the references and former employers named by him, but also with others who may be acquainted with the applicant and his work. Such investigation will necessitate not only extensive correspondence, but also personal interviews in many cases. It being apparent that, at the present time, the Civil Service Commission does not have the organization necessary adequately to investigate experience sheets, the committee recommends that a trained investigator be added to the Commission's staff, to do this follow-up work in a thorough and proper manner.

5. *Character of Examination.* The applicant's standing in examination should be determined as at present, both from his experience sheet and from written tests. It has been suggested to the committee that for the highest grade (senior assistant engineer) the written examination should be dispensed with altogether and the applicant's standing determined solely from his experience sheet, supplemented by such oral examination as the special examiners deem necessary to fully ascertain the facts of the applicant's training and experience. While much may be said in favor of this suggestion, the committee foresees difficulties which would be likely to arise from the adoption of such a plan, and believes its introduction is not feasible, — at least until the Civil Service Commission has the proper organization thoroughly to investigate experience sheets; accordingly the committee recommends the continuation of the present practice of requiring applicants for examination in every engineering grade to pass written tests. No material change from the present practice is suggested, either in the subjects covered or in the character of the questions asked in the written examination, the committee feeling that this is a matter which the examiners have well in hand. Much less importance should be attached to the written examination in comparison with the experience rating than is the case at present, however, the specific recommendations on this point being given in the following paragraph. Further provision should be made so that the examiners shall

have the right, at their discretion, to subject applicants in any grade to oral examination, and this right should, it is believed, be generally exercised in the case of applicants for grades of junior and senior assistant engineer, as thereby the examiners will be better able to gage an applicant and give him his proper rating for experience.

6. *Weights to be Assigned in Examination.* The committee is strongly of the opinion that the relative weights assigned to written examinations at present are contrary to the best interests of the Service and such as to discourage able and experienced engineers from taking examinations for the higher grades in competition with younger and less experienced engineers, who, being more recently out of a technical school, are consequently less rusty in the theoretical subjects of the written examinations. The higher the grade the greater should be the rate allowed for experience and the less that allowed for written examination. The committee is of the opinion that a very considerable weight should be given for experience in the grades of junior and senior assistant engineer. On the other hand, it recognizes the limitations of the present organization of the Civil Service Commission for the investigation of Experience sheets, and accordingly, it recommends a set of weights for adoption at the examinations to be held in December, 1917, and another set of weights to be adopted after the Commission's staff has been strengthened adequately to investigate the experience of the applicants. In the following table, Group I shows the weights assigned at present; Group II, those recommended by this committee for the 1917 examinations, and Group III, those recommended for ultimate adoption.

In the case of applicants for admission to Grade A (rodman) who are graduates of a school of engineering of recognized reputation authorized by law to confer degrees, the committee recommends that graduation shall of itself count as a credit of 80 per cent. of the total experience mark, leaving 20 per cent. additional to be gained by the engineering graduates, who, in addition, have had actual field experience. As to the credit for experience to be given to graduates from such an engineering school, in the case of applicants for other grades, the committee recom-

GRADE.	GROUP I.		GROUP II.		GROUP III.	
	Weights Assigned at Present.		Weights Recommended for 1917 Examinations.		Weights Recommended for Ultimate Adoption.	
	Points, of Total	Per Cent. Rating.	Points, of Total	Per Cent. Rating.	Points, of Total	Per Cent. Rating.
A — Rodman or E — Junior Draftsman	{ Experience Written examination	5	2	20	2	20
		11	8	80	8	80
B — Instrumentman F — Senior Draftsman	{ Experience Written examination	5	4	40	4	40
		11	6	60	6	60
C — Junior Assistant Engineer	{ Experience Written examination	5	5	50	6	60
		13	5	50	4	40
D — Senior Assistant Engineer	{ Experience Written examination	5	6	60	8	80
		13	4	40	2	20

mends that this matter be left to the discretion of the Civil Service Examiners.

7. *Provisional Appointees.* In the case of provisional appointees, the committee is of the opinion that no provisional appointment should be made permanent, and no provisional appointee should be eligible for an increase in compensation, until such appointee has passed the examination for the grade to which he has been provisionally appointed.

8. *Retention of Names on Eligible List.* As a remedy for the unsatisfactory condition now existing by which names are automatically dropped from the eligible list at the end of two years, the committee recommends a modification of Rule 18 to provide that if, before the expiration of the original two years, the applicant so requests in writing, his name shall be retained on the list for an additional year; and, by written application made before the expiration of such additional year, further extension of a year may be granted; this to continue until the applicant's name has been retained on the list for a total period of at least five years.

9. *Certification of Names from Both State and Local Lists.* The eligible lists for all engineering grades in cities outside of Boston, and for the higher grades in Boston, being usually non-existent or containing an insufficient number of names to furnish the quota necessary to give the appointing officer the choice which is his right, the committee recommends that where the local list fails to supply the requisite number of names for certification, the lack be supplied by certification of names from the State list. This will probably do away, to a large extent, with the present practice of making provisional appointments in cities, especially those outside of Boston, in which there are no eligible lists or lists of insufficient names.

10. *Standardization of Work and Pay of Engineering Employees.* The committee is informed that an investigation is under way with a view to standardizing the work and pay of all state employees, including the civil engineering staffs of the state departments, and that the suggestion has been made, first, that the classification of engineer and draftsman should be wholly separate and distinct; and, second, that there should be

more classifications of engineers with pay graded in each classification. In regard to the first suggestion, the committee doubts the wisdom of separating draftsmen and engineers, and believes that they should both be included in the general classification of engineers.* The second suggestion regarding the classification of engineers and the grading of pay within the several classifications is evidently based upon the New York City Tentative Specifications for Professional Service, recently submitted by the Bureau of Standards to the Board of Estimate and Apportionment. In this connection the committee would point out that there is a fundamental difference between the Civil Service system of Massachusetts and that of New York and most other states. Elsewhere, state service and municipal service are wholly distinct so far as Civil Service regulation is concerned. New York City has its own set of Civil Service laws, rules and regulations, while an entirely different set applies to the Civil Service of New York State. In Massachusetts, however, all of the municipalities, as well as the several state departments, are comprised within the single Civil Service system. Having in mind rules and regulations which must be applicable alike to the municipalities and to the state departments, the committee is of the opinion that it would be unwise to increase the number of engineering grades beyond that recommended in this report; moreover, the committee doubts the wisdom of attempting to grade the rates of pay within each engineering grade for general application to all departments, as has been suggested in New York City. The grading of pay apparently requires legislative action, as evidenced by Chapter 605, Acts of 1914, establishing the grades for salaries of clerks and stenographers in departments of the Commonwealth. Further, it is believed that conditions applicable to New York City with many departments, each with a large engineering staff, would not apply to all of the state departments, or to all municipal departments, especially those in cities outside of Boston or even to some departments in

* The committee has since learned that, while, in general, it is proposed to separate draftsmen and engineers, consideration is being given to the proposal to include within the engineering classification those who may be termed "engineering draftsmen" in distinction from draftsmen who have not had special engineering training.

Boston itself. In many of these departments the number of engineering employees is so small and the conditions pertaining to their employment in the several departments and cities is so varied that, in the opinion of the committee, rigid grading of pay would not prove to be equitable alike to the engineering employees and to the state or the municipality which employs them.

Respectfully submitted,

(Signed) JOHN E. CARTY,
CHAS. R. GOW,
EDWIN H. ROGERS,
RUFUS M. WHITTET,
FREDERIC H. FAY, *Chairman.*

BOSTON, September 13, 1917.

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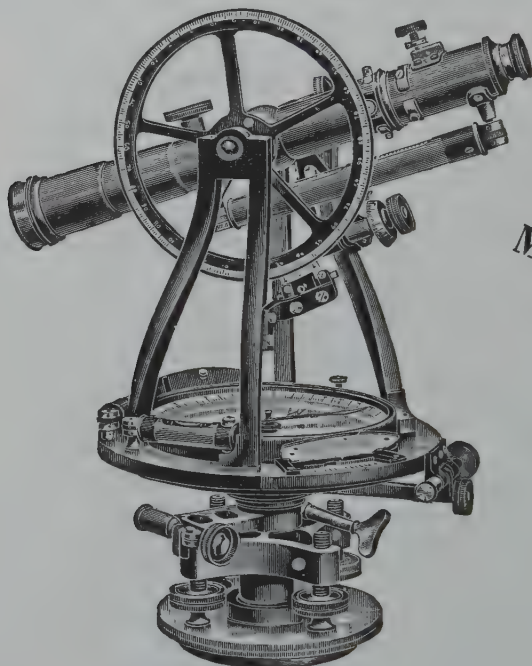
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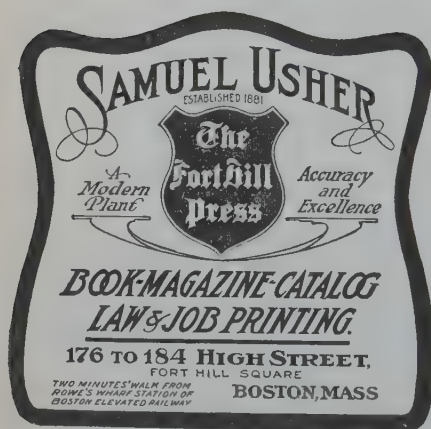
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